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# THE ROLE OF POLLEN IN THE ECONOMY OF THE HIVE 1/

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Scientific investigations have shown that insects, like mammals, have definite needs for the various kinds of foodstuffs, including carbohydrates, proteins, fats, minerals, vitamins, and water. The honeybee derives these food materials from nectar, pollen, and water.

Nectar is the chief source of carbohydrates in the honeybee's diet. In the ripening process the nectar sugars are converted into the readily digestible sugars dextrose and levulose, and the solution is concentrated by the reduction of the water content. Honey is therefore a highly concentrated source of energy. It supplies the bee with energy for flight, vital processes, fanning the nectar, and its many other activities. The sugars in honey are also converted into beeswax.

## NUTRITIONAL VALUE OF POLLEN

Pollen is the chief source of all the other foodstuffs required by the bees, except water. It provides much of the material for making royal jelly, which nourishes young larvae and queens. From pollen come the materials out of which are made the muscles, vital organs, glands, hairs, wings, etc. It also furnishes material for the repair of worn-out tissues. Pollen is therefore essential to the growth of the individuals and to the reproduction and development of colonies.

Chemical analyses of pollens have shown them to be rich in protein and fats, and also to contain the carbohydrates, sugar, starch, and cellulose. In them have been found various minerals--calcium, magnesium, phosphorus, iron, sodium, potassium, aluminum, copper, manganese, sulfur--as well as vitamins (9), enzymes, and pigments (xanthophyll and carotene).

The composition of pollen is by no means uniform. The analyses of 34 samples (5) of pollen gathered by bees from different plants showed that the protein content varied between 7 and 35 percent, and that fats, starches, and minerals varied widely. Nicotinic acid, thiamine, riboflavin, pantothenic acid, ascorbic acid, and vitamins A and E are present. It therefore appears probable that the food value of pollens from different

1/In cooperation with the University of California.

sources varies widely. More of some pollens than of others must be eaten to produce the same brood-rearing results, and perhaps a mixture from several sources is necessary to give the bee a complete diet.

Far less is known about the nutrition of bees than is known about the nutrition of livestock and poultry. In view of the great advances in egg production that have resulted from scientific feeding of poultry, one wonders what the limits of honey production might be if, through feeding, the colony population could be regulated to provide a maximum bee force at the time of honey flows.

The pollen supply unquestionably limits the production of brood and affects colony development. The brood-rearing cycle, which rises to a peak at swarming time and reaches its lowest level in winter, seems to bear a definite relation to the pollen reserve in the hive.

In the Sacramento Valley the pollen sources are both native and cultivated. The trap record shows a pollenless period in winter, when there is a cessation of brood rearing. A dearth in May and June is also indicated, which is preceded by the fruit bloom of March and April and followed by moderate pollen supplies from star-thistle and fall weeds. The brood rearing is closely correlated with these trends. Production of package bees takes place on the large spring supplies of pollen. During the peak early in April one-half pound of pollen was brought to the hive each day for 2 weeks.

In the Sierra Nevadas the peak of pollen income occurs during the dearth period of May and June in the Sacramento Valley. Many beekeepers move their bees to the mountains in order to maintain brood rearing during this period, and return to the valley for the star-thistle flow in July. The writers have moved bees from the Sacramento Valley to mountain locations at 2,000 and then at 6,000 feet, and obtained three swarming periods for the same colony within the year. The low pollen income during the fall has proved disastrous to colonies left in the mountains over winter.

Pollen cycles are determined by the blossoming succession of the flora of the area. The commonly designated minor honey plants furnish much of the pollen, and many plants not recognized in this category have been found to be important pollen sources. In view of the correlation of pollen income with colony population and the effect of population on honey production, minor honey plants are just as important to productive beekeeping as are the major nectar sources.

Traps maintained in the same localities for 2 years have shown similar seasonal trends in the pollen cycle. The size of the field force during periods of pollen abundance appears to influence the amount gathered by a colony. Two colonies side by side may bring in quite different quantities during the same period, and yet the trends in the pollen cycle will be similar. The quantity gathered may be limited by weather conditions inhibiting field activity and length of working day. Certain good nectar sources--orange, lima bean, vetch, alfalfa, fireweed, etc.--are of little value as pollen sources. At the time of such nectar flows the pollen supply

must come from other sources or brood rearing will decline. On the other hand, sage, sweetclover, and star-thistle are good sources of pollen as well as nectar, and flows from these blossoms are not accompanied by decline in brood rearing.

## EFFECT OF POLLEN INCOME ON THE COLONY

The condition of colonies in relation to pollen income and to honey flow in the southern California Orange Belt throughout the year, as obtained in studies at Orange, Calif., is shown in figure 2.

The pollen income was determined by trap records from a colony during 2 years, and the daily gain or loss in weight was determined by scale-hive weights of a colony during 1938. These data are therefore of value in showing trends rather than the actual quantities of pollen or nectar coming to the colonies from which the respective curves were determined.

Counts of sealed brood and population of a number of colonies were taken at intervals during a 4-year period, and from these a colony showing typical conditions throughout the year 1938 has been selected for presentation in figure 2. The brood-rearing curve was determined by counts of sealed cells from photographic records. The population cycle was constructed from the brood-rearing cycle and falls in line with actual population counts taken throughout the year.

The diagonal lines of figure 2 indicate the course of development of bees from egg to adult and adult to field-bee age. For example, an egg laid on January 1 becomes an adult on January 21, and a field bee on February 11. The last date is probably not so definite as the line indicates. The population is composed of the younger or house bees and of older or field bees. The proportion of these two classes of bees is constantly changing during the year; for example, the proportion of the population of field-bee age was: April 5, 42 percent; April 26, 51 percent; May 17, 58 percent; June 7, 50 percent. The proportion of the population in each class varies with the brood-rearing activity during the preceding 6 weeks. If brood rearing has been expanding, house bees will be predominant, but if it has been contracting, the field bees will predominate in the population.

The most striking feature shown in figure 2 is the two-peak character of the pollen-income, brood-rearing, and population cycles. When due allowance is made for the time factor--i.e., for eggs to become sealed brood and for sealed brood to become adults--there is an apparent close relationship between these three cycles. A closer study of the chart in the light of the main features of the beekeeping season discloses other relationships, which will be discussed in the following paragraphs.

### The Spring Build-up Period (December-March)

It will be observed in figure 2 that brood rearing is at its lowest ebb in November. The spring build-up of the colony starts in December, following a moderate rise in pollen income coincident with the blooming of eucalyptus. Pollen samples trapped during December and January are pre-

dominantly from eucalyptus, and those taken in February and March from mustard, although there are usually representatives from miscellaneous sources. Mustard is a common cover crop in the orange groves and is turned under during the latter part of March. This cutting off of pollen sources causes a decline in the pollen income at this time.

The brood-rearing cycle follows rather closely the pollen-income curve. When due allowance is made for the time necessary for eggs to become sealed brood, it is apparent that the peak of egg laying occurred early in March during the peak of the pollen income.

During this spring upswing in brood rearing there were more bees being reared than old bees dying off; consequently there was a rapid increase in colony population after the middle of February. The peak of population was reached about 35 days after the peak of pollen income. Therefore, on the spring upswing in colony development the population peak may be expected about 5 weeks after the amount of incoming pollen is at a maximum.

The April population peak (about 45,000) would not be considered a strong honey-flow colony in some localities; yet it appeared to be common here. The November pollen reserves were the lowest for any area studied, with an average of 30 to 40 square inches. Likewise, the pollen income during the spring was comparatively low (fig. 1). During the last part of March the colonies showed little or no reserve. Pollen present in the cells in the afternoon was gone by the next morning. It was evident that insufficient pollen was coming into the hive to support the amount of brood carried; in other words, the colonies were living from hand to mouth. Ordinarily, when enough pollen is available to supply the brood-rearing needs, a small reserve is carried along. The absence of such a reserve is an indication that there has been or is insufficient pollen available. There is an apparent tendency for colonies to rear brood to the limit of the food supply, and lack of pollen during the build-up period may be the factor restricting colony population in this area.

The apparent tendency to rear brood to the limit of the pollen supply may be modified by other factors, which may cause a lag in the use of pollen and result in the building up of a reserve. Among these factors may be mentioned the egg-laying capacity of the queen, the size of the bee force to care for the brood, and available cells for egg laying.

## The Swarming Period

In any locality the swarming season is a well-defined period occurring at about the same time each year but varying in intensity from year to year. In the California Orange Belt swarming occurs in April and early in May. It is of interest, therefore, to note the conditions occurring at that season of the year.

In figure 2 it will be noted that just prior to this period there is a sharp decline in pollen income. The colony has reached a population peak, and brood rearing is being sharply curtailed. On the other hand, during late summer and fall (August to October) pollen income, brood rearing, and

colony population decline more gradually and swarming does not occur.

This situation suggests that the swarming season may be intimately tied to the availability of pollen in a locality. The sharp decline in brood rearing, which is a recognized part of the swarming phenomenon, may be related to pollen income.

### The Honey-Flow Period

The orange blossoms, which appear chiefly during April, are the only source of surplus honey in this section. Unlike many honey plants these blossoms furnish little or no pollen. During this period other pollen sources are meager until the olive blooms toward the end of the month, when pollen income again increases. In spite of the population peak, only small quantities of pollen were brought to the hive, because of its absence in the field.

It will be noted that the peaks of both population and honey flow occur during April, but when allowance is made for the age of nectar-gathering bees it appears that a broader and earlier peak might be more desirable from a honey-gathering standpoint. Some modification of the brood-rearing cycle is possible by additions to the pollen reserve (4) at certain seasons. The addition of pollen to the reserve in November resulted in a greater population during the honey flow and a tendency to build up the population earlier in the season, but it did not modify the general trends of the brood-rearing cycle. The brood-rearing cycle can also be modified by moving bees to locations in which there is a cessation of brood rearing during the winter, thus conserving the pollen reserve, or to areas having more abundant early spring sources. Addition to the pollen reserve in March lessened the decline in brood during April and the population in May; that is, it tended to smooth out the curve. Variation in the pollen reserve at critical periods may be one cause of the variation in the bee force of colonies found in any apiary at honey-flow time.

### The Summer Period

After the April honey flow bees hardly make a living as far as bringing in nectar is concerned until the eucalyptus flow occurs in December. The second population peak is therefore of little value for honey production in this section. There is, however, a more abundant supply of pollen coming from olive, English walnut, and acacia in May, and from various ornamentals and grasses in the summer. Even during this period pollen income does not equal that obtained during the spring in other areas, and since it is used in summer brood rearing, by fall the pollen reserves are light.

## QUANTITY OF POLLEN USED IN BROOD REARING

The quantity of nitrogen required to rear one bee, which has been determined by Haydak (2) as 3.21 mg., gives us a clew to the amount of pollen that may be required to support the brood rearing of a colony. The average

percentage of nitrogen contained in the various pollens so far analyzed is 3.1. From these figures we calculate that 100 mg. of pollen will supply sufficient nitrogen to rear one bee. One pound of pollen will therefore produce 4,540 bees. Nolan's studies (3) indicate that about 200,000 bees are reared by a strong colony during a year, which would require on this basis 44 pounds of pollen. Forty-four pounds of pollen in uncrushed bee-load pellets would fill 66 pint jars. The writers have actually trapped 71 pounds of pollen from one colony in a single year.

Pollen enters the hive not alone as pellets on the bees' legs. On certain flowers the body hairs of nectar gatherers become coated with pollen, which is not brushed into the pollen basket. Such pollen-coated bees enter the hive but are cleaned up before returning to the field again. Pollen grains are abundant in some nectars (6). The adult bee has an organ at the lower end of the honey stomach, the proventricular valve, which appears to remove pollen grains from nectar automatically while it is being carried in the honey stomach, thus reducing the pollen content of the resulting honey. This pollen is swallowed and presumably digested by the bee. No doubt the house bees in ripening and storing the nectar also obtain pollen from it in like manner. Pollen entering the hive thus is not caught in the pollen traps, and therefore we have no measure of its quantity.

The relative quantities of pollen pellets of various sizes have been determined from the samples trapped at Davis, Calif., throughout the year. Of the total pellets trapped, 20 percent were large, 72 percent medium, and 8 percent small. By means of counts of measured samples of each size group and these percentage figures, it has been estimated that 10 average bee loads of pollen are necessary to produce one bee, 112,000 to produce a 3-pound package, and 2,000,000 to bring in a year's supply for the brood rearing of one colony. The colony under observation at Davis has carried in 1,747,622 bee loads of pollen this year.

The pollen reserve has received considerable attention recently through the work of C. L. Farrar at Madison, Wis., on wintering colonies. He has estimated that about 600 square inches of pollen is required to maintain colony strength from fall to spring under northern conditions. How much pollen is this? The writers have weighed and measured cells of stored pollen and find that, on an average, pollen cells are slightly over one-half full and the packed pollen weight averages 143 mg. per cell. On this basis a cell of pollen would be sufficient to rear 1 1/3 bees, 100 square inches would be necessary for a pound of package bees, 600 square inches for about 21,000 bees, and 22 full frames to hold the year's supply for a strong colony.

The pollen picture is not complete if it fails to include the invaluable service to agriculture which the pollen-gathering habit of bees renders. A few data have been obtained on the number of flowers visited by bees to get a load of pollen. Dunham (1) estimated that 346 red clover florets were visited to get a load of pollen from that plant. Vansell (7) observed a bee visiting 84 Bartlett pear blossoms to get a full load. About 350 alfalfa blossoms are tripped to obtain a full pollen load (8). These plants appear to be about the extreme types of pollen sources. Two million times any of

these figures is an enormous number of blossoms to be visited by one colony during a season in the collection of pollen, and incidentally gives some idea of the value of the honeybee to agriculture in the pollination of seed, fruit, and vegetable seed crops.

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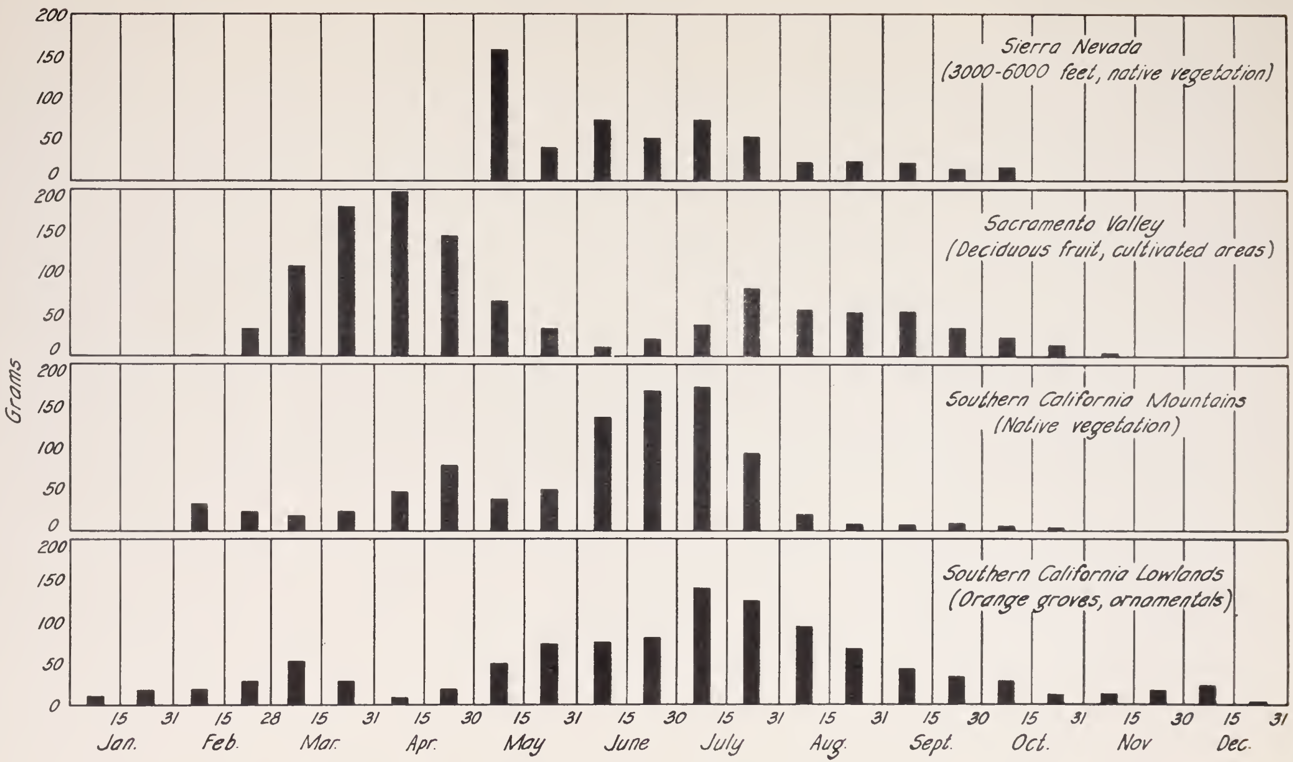


Figure 1.--Average number of grams of pollen trapped per day during semimonthly periods in four sections of California.

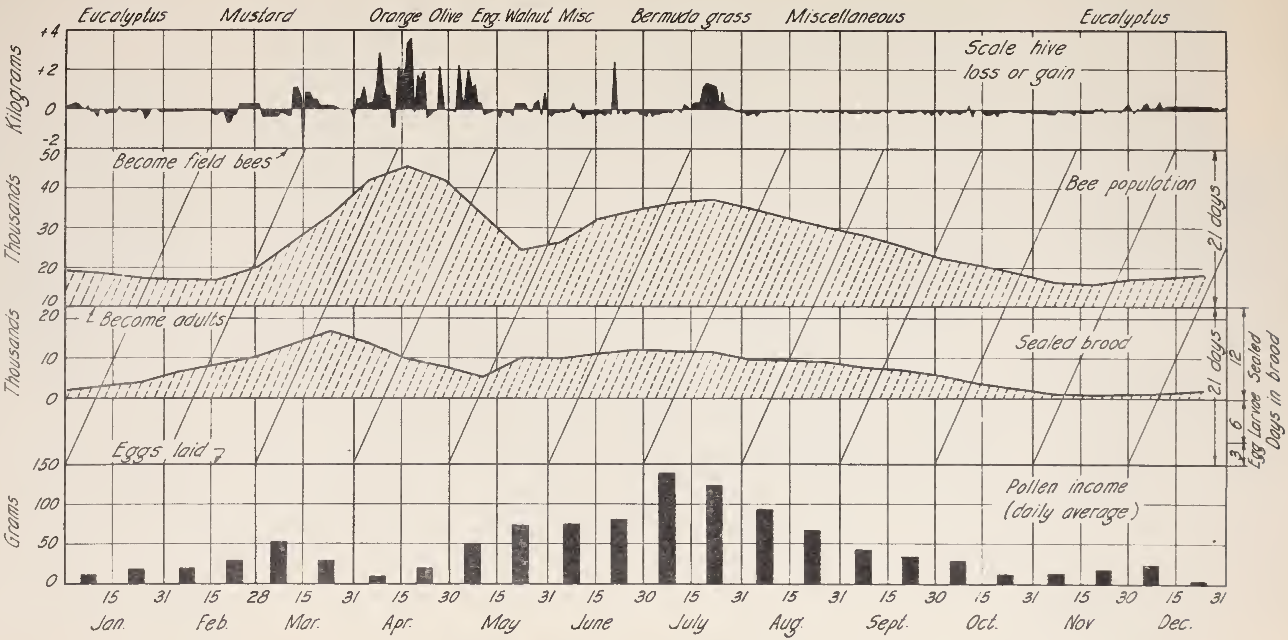


Figure 2.--Relation between trends in pollen income, honey flow, brood rearing, and colony population at Orange, Calif.